Analysis of the impacts of small-scale orography on the atmospheric boundary layer. Developing ICON-LES for the Perdigão field experiment.

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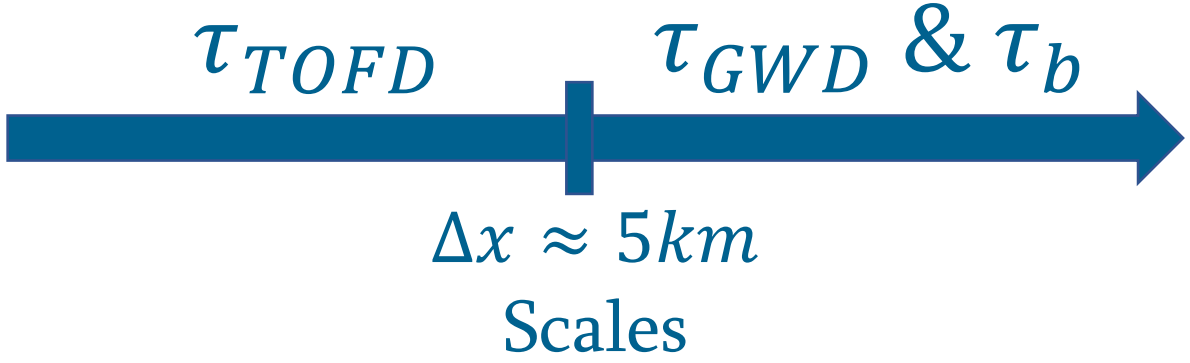
The general goal

The overall goal is to improve the representation of the drag exerted by the orography in NWP models.

$$Drag = \tau_{GWD} + \tau_b + \tau_{TOFD}\ *$$



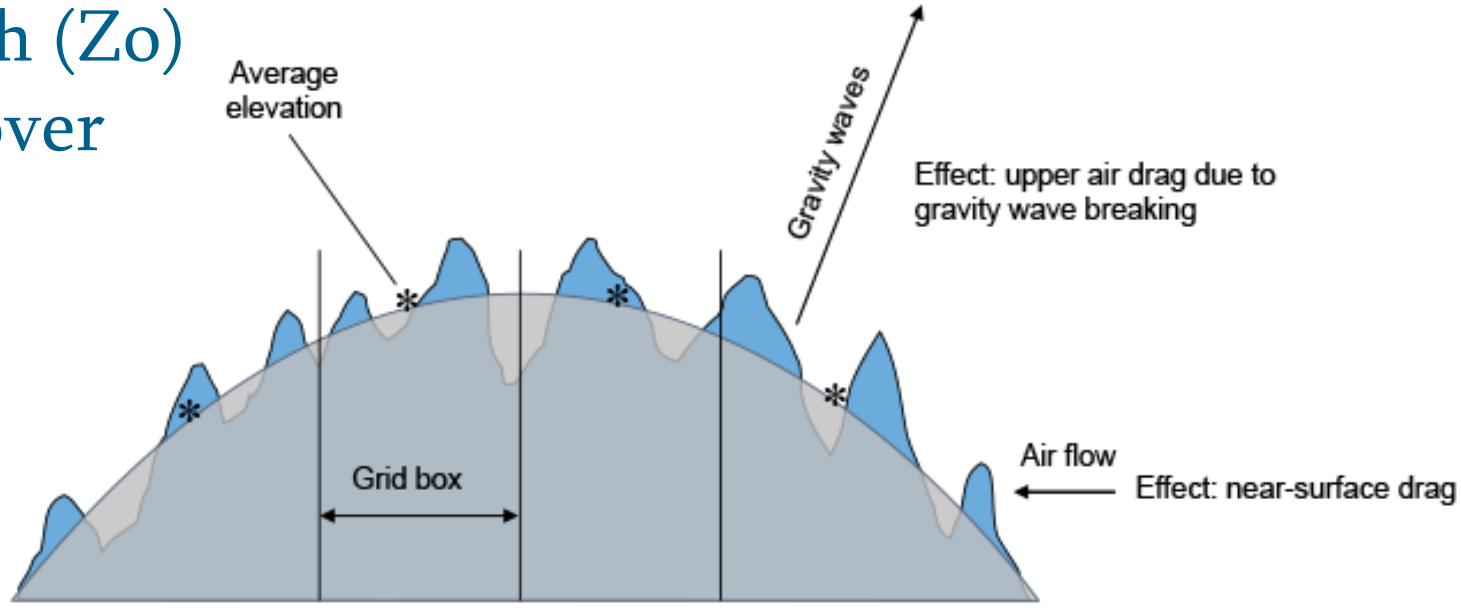
*Turbulent orographic form drag

ECMWF (2003)

Background

What is currently doing ?

A popular way to represent the effect of unresolved orographic features is to enhance the roughness length (Zo) with respect to momentum over orography.



ECMWF (2016)

Background

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What is currently doing ?

A popular way to represent the effect of unresolved orographic features is to enhance the roughness length (Zo) with respect to momentum over orography.

Disadvantages:

- Low level flow is spuriously low in regions with high effective roughness.
- Hard to understand the interaction of the scheme with stability and orographic wave drag / flow blocking schemes

Background

What can be done for a more realistic approximation?

Beljaars et al., (2004).
Get the the geometrical parameters on a global scale is hard to achieve from current global data sets.

$$\overline{\theta^2} = \int_{k_0}^{\infty} k^2 F_o(k)\, dk,$$

$$\frac{\partial}{\partial z}\left(\frac{\boldsymbol{\tau}_o}{\rho}\right) = -2\alpha\beta C_{md} C_{corr} |\mathbf{U}(z)| \mathbf{U}(z) \int_{k_0}^{k_\infty} \frac{k^2}{l_w} F_o(k)\, e^{-z/l_w}\, dk$$

Instead, the orographic spectrum is parametrized and the effect of all the scales is obtained by integrating over the spectrum.

$$F_o(k) = \begin{cases} a_1 k^{n_1} & \text{for } k_0 < k \leqslant k_1, \\ a_2 k^{n_2} & \text{for } k_1 < k < k_\infty, \end{cases}$$

The Experiments

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ICON-LES:
Phase I: Perdigão field experiment

#	Experiment	Setup
1	LR_ctr	Low resolution (about 1 km) with TOFD off (NWP)
2	LR_test	Low resolution (about 1 km) with TOFD on (NWP)
3	HR_LES	High resolution (about 100 m) in LES

Some context

Perdigão field campaign: Dec 2016 – June 2017

- IOP: 30th April 2017 – 15th June 2017.
- Dense instrument ensemble deployed covered a ~4 km × 4 km swath horizontally and ~10 km vertically.
- Meteorological data were collected continuously, capturing multiscale flow interactions from synoptic to microscales, diurnal variability, thermal circulation, turbine wake and acoustics, waves, and turbulence.

1.5 km width and 150 m deep.

Fernando et al., (2018)

Model Setup

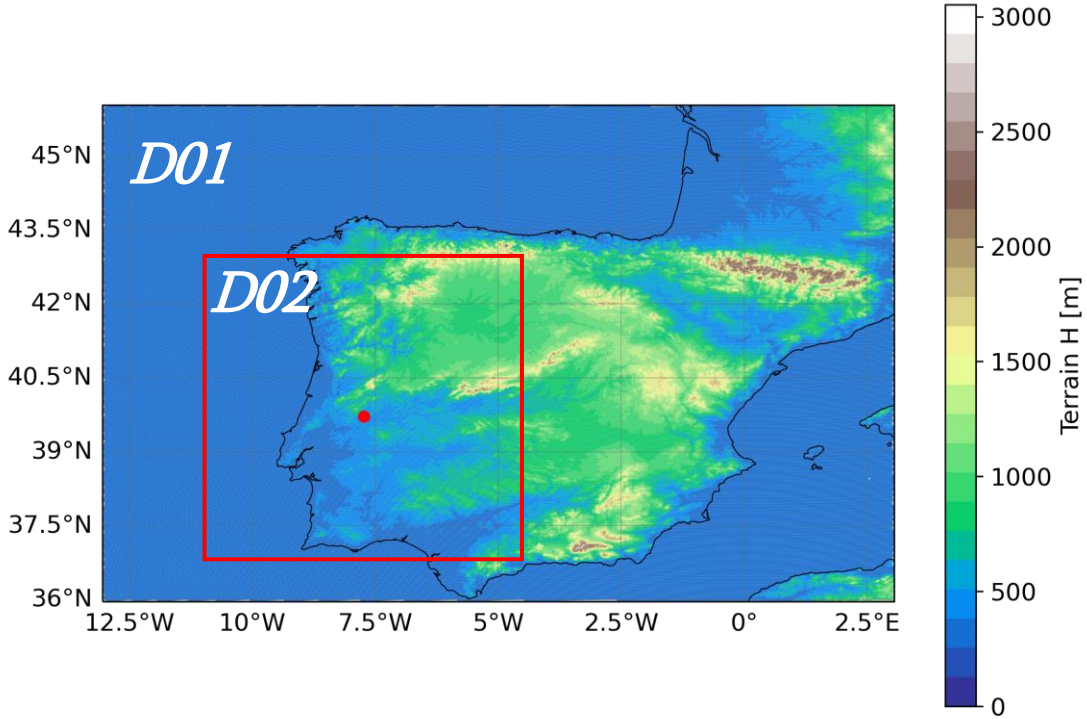
- ICON-NWP:: Control case

- Nested domains centered in field exp location:

D01=R19B07 (326256 cells) ≈ 2077m*
D02=R19B08 (298368 cells) ≈ 1036m

- Model top = 22km

- NWP have an integration time of 60 days (00h00 20-04-2017 -> 00h00 19-06-2017). 10 days spin-up (soil fluxes) + 50 days simulating the field campaign.



*ICOND2-like configuration

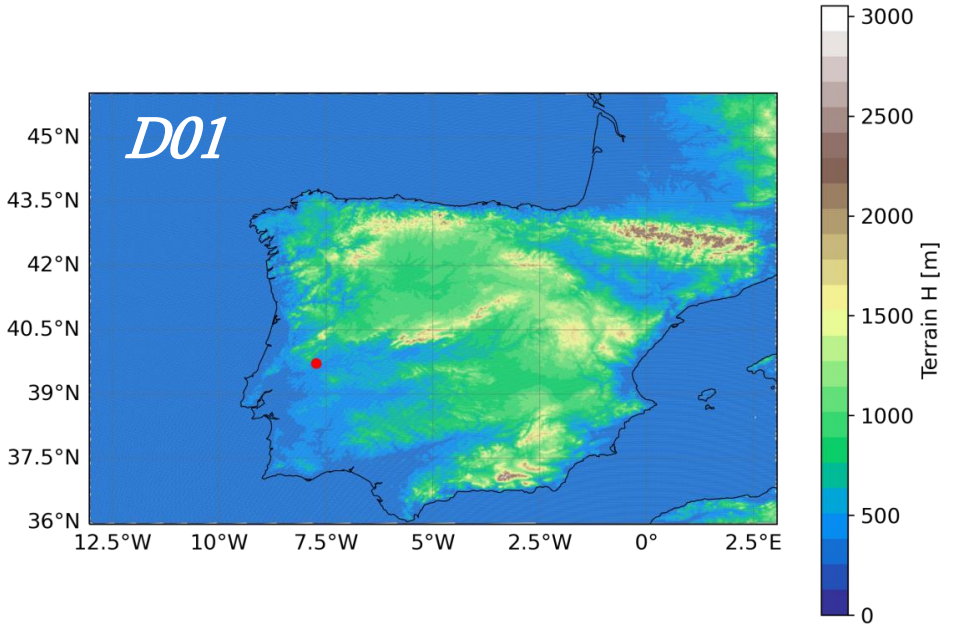
Model Setup

- Initial and boundary conditions for D01 ERA5 reanalysis
  - 137 model levels
  - horizontal resolution of 0.25°
  - temporal resolution of 3 h

- Terrain:

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER 30m) topography data set (Schmugge et al., 2003).

Soil type: HWSD soil type (30” resolution)



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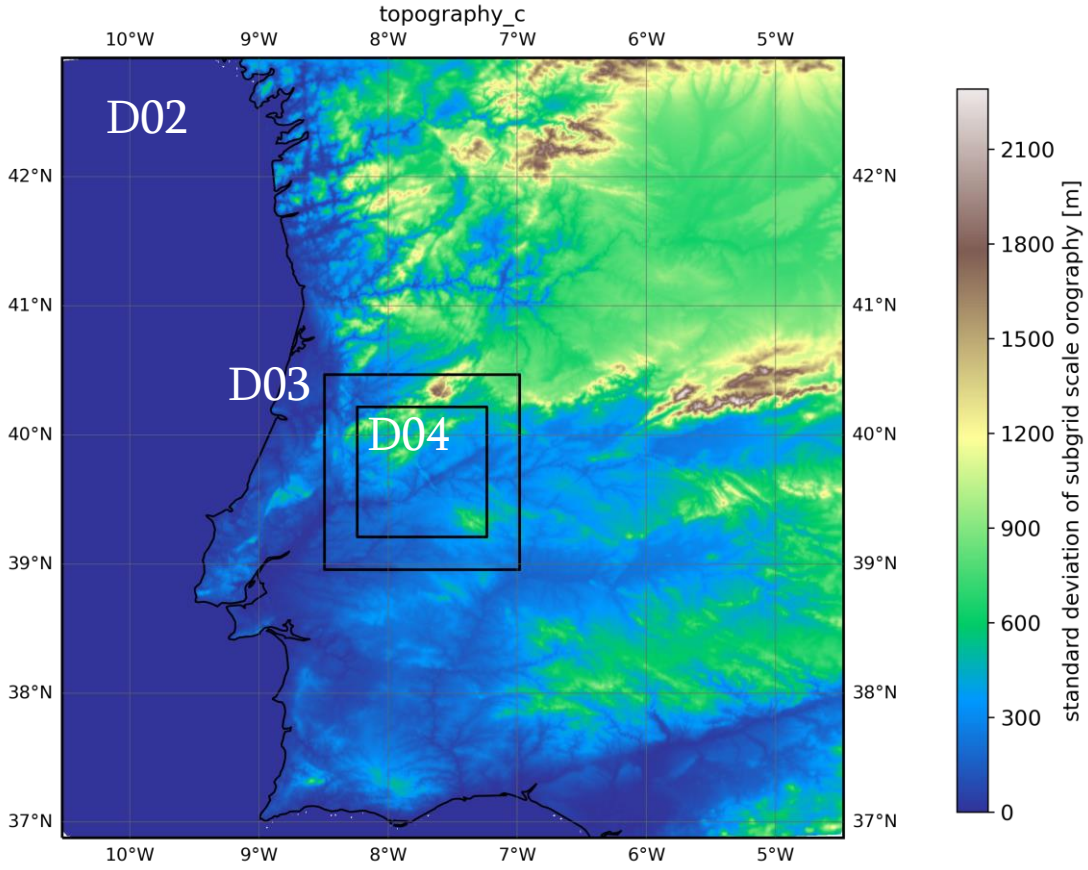
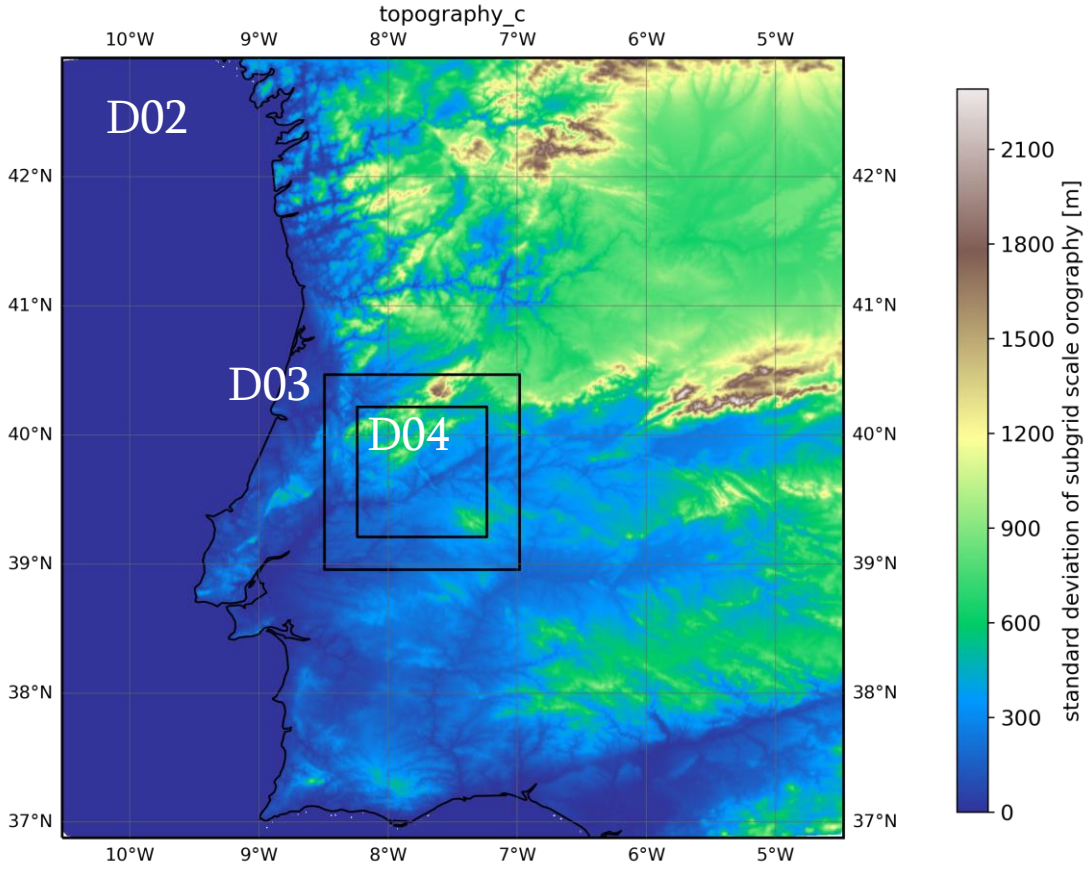


Online nesting

Model Setup

ICON LES:

- Two (D03 [260 m] and D04 [130 m]) Nested domains into ICON NWP (offline).
- Boundary updated every 30 min.
- Same vertical coordinate.
- Integration time: 46 days



Preliminary results

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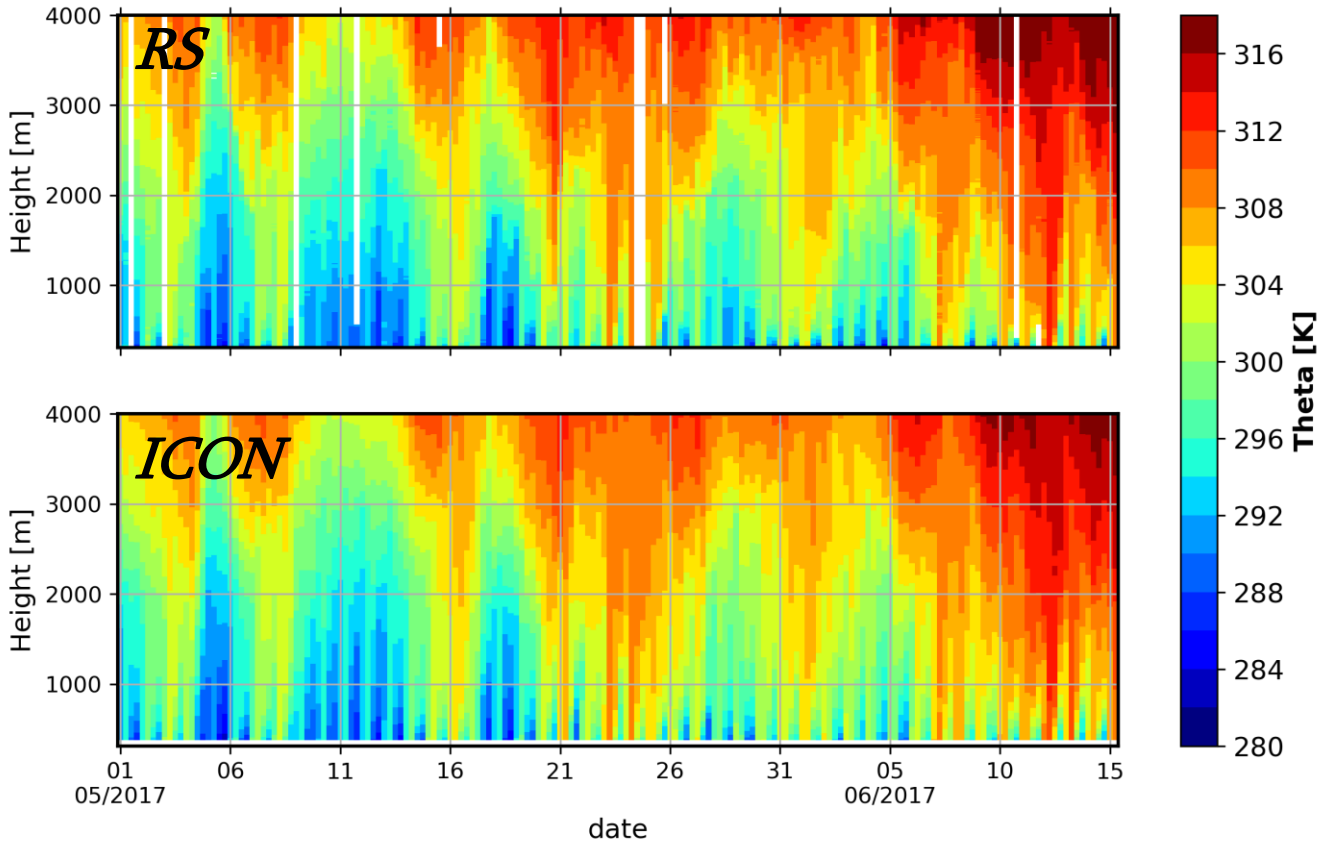
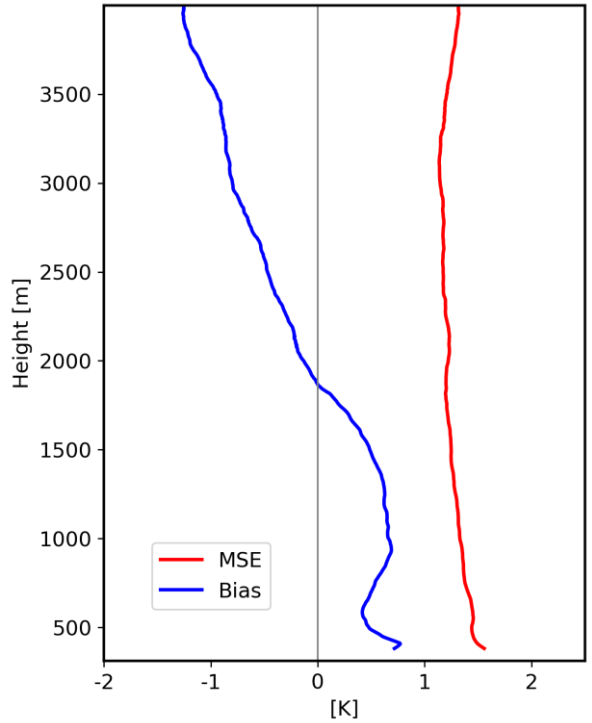
Thermal structure of the atm:

Potential temp from Radio soundings Vs ICON every 6hr



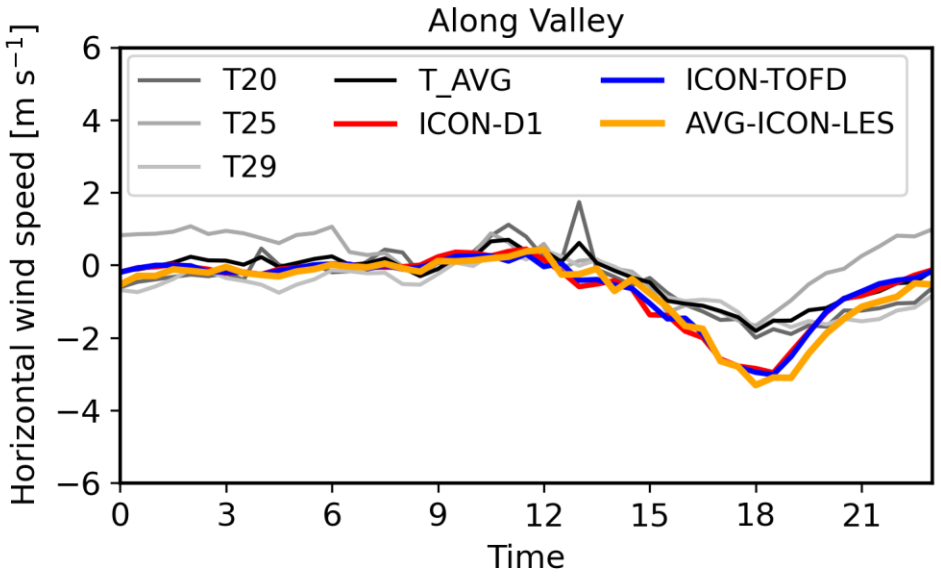
Quantitative comparison

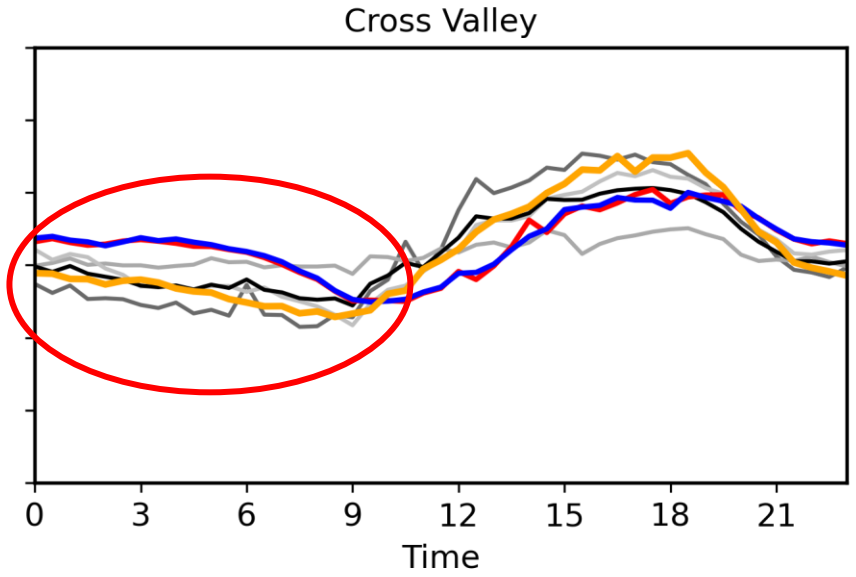


MSE & Bias

Daily average for the 49 days

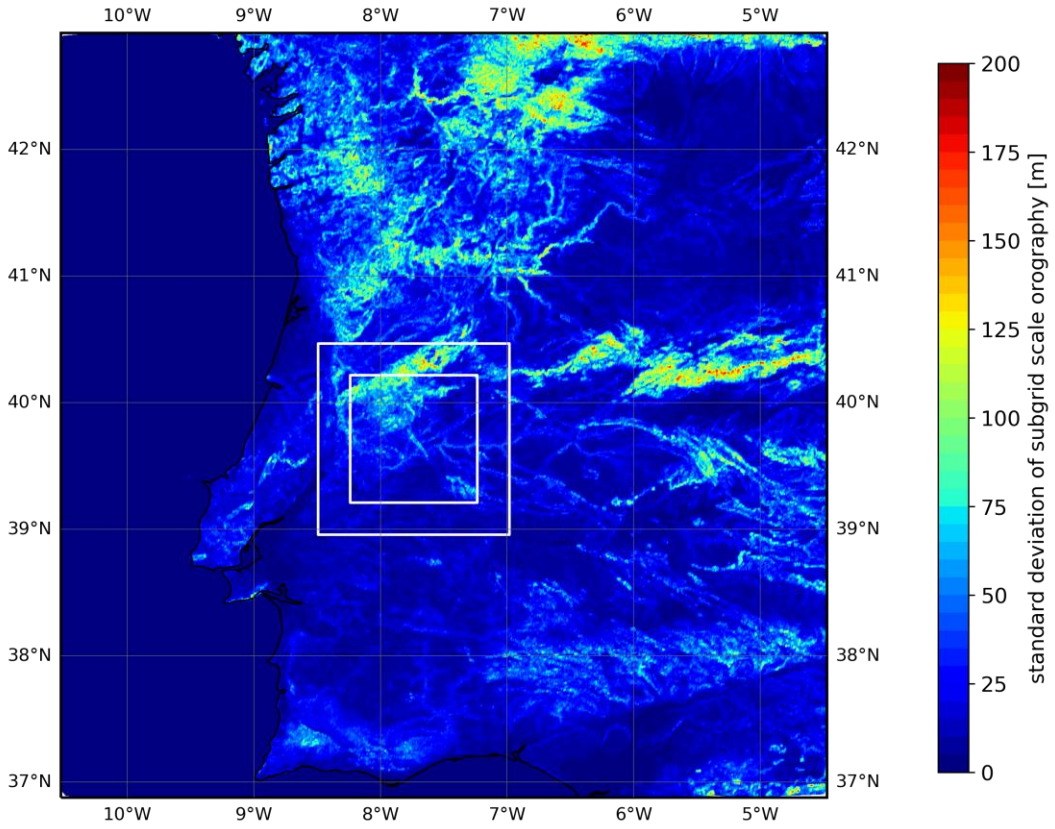
Default NWP configuration:

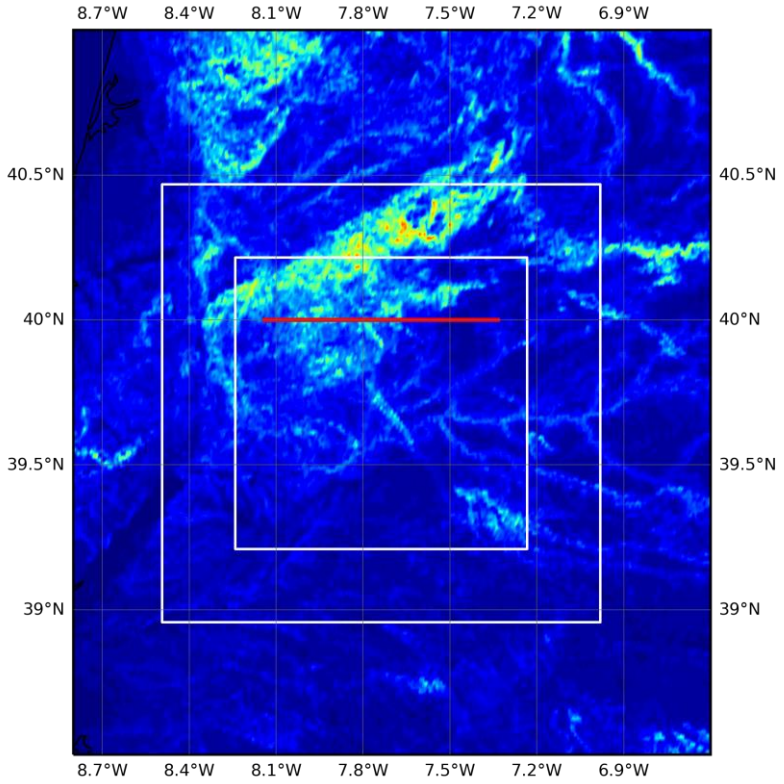




Std H

Dom d02 (1 km)





Lat 40° Cross-section: 07/05/2022 4h00

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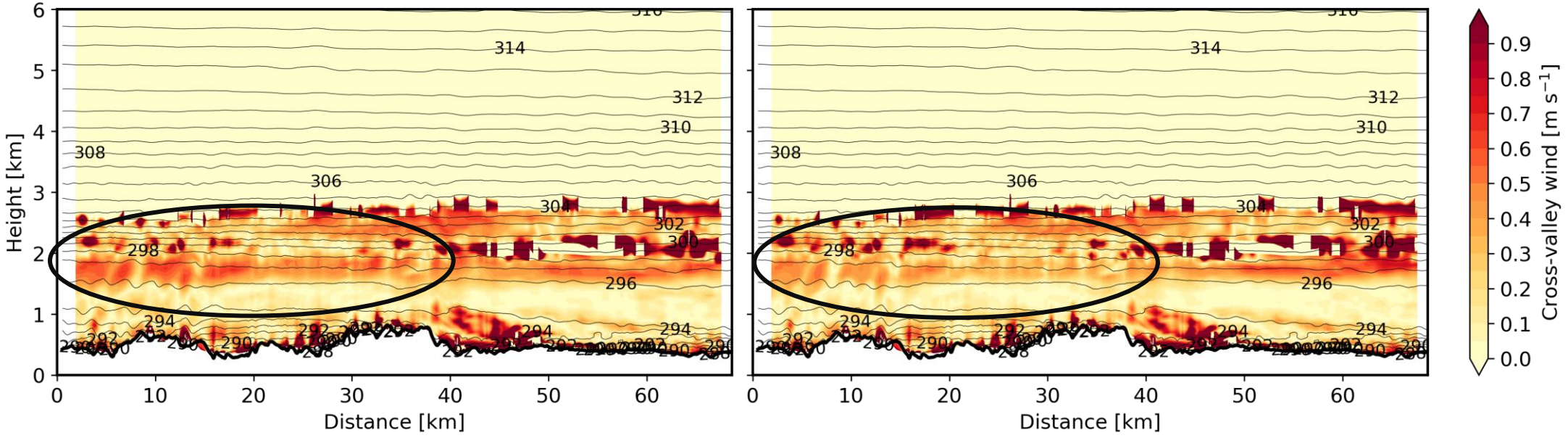
With respect to the LES 130m: Normalized with the LES

Ctrl

TOFD



Conclusions + Future work

- ICON-NWP and LES showed a good performance when compared with observations, meaning that we can trust in the model in this setup.

- TOFD parametrization seems to improve the simulations over complex terrain near the Perdigão site. However, further investigation on the tuning of the TOFD parametrization is required.

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Thank You!

Questions?

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